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(54) **METHOD AND DEVICE FOR PROCESSING AN IMAGE TO REMOVE COLOR FRINGE**

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2209/00322; G06T 3/403; G06T 3/4015; G06T 5/003; G06T 5/005; G06T 7/0081; G06T 7/0083; G06T 7/0091; G06T 7/0095; G06T 7/0097; G06T 2200/24; G06T 2207/30201; G06T 2207/10024; G06T 2207/20036; G06T 2207/20064; G06T 2207/20141; G06T 2207/20144; G06T 2207/20148

See application file for complete search history.

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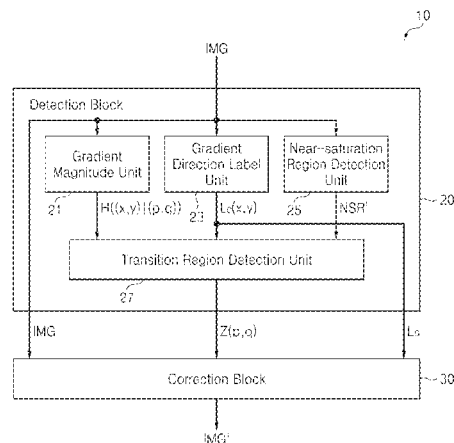(Continued)

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(57) **ABSTRACT**

In image processing, a color fringe is removed. The processing includes selecting a maximum gradient magnitude among gradient magnitudes for each of color components in an image, calculating a boundary of a dilated near-saturation region in the image, detecting a transition region in the image according to the maximum gradient magnitude and the dilated near-saturation region, and removing a color fringe from the transition region.

20 Claims, 19 Drawing Sheets

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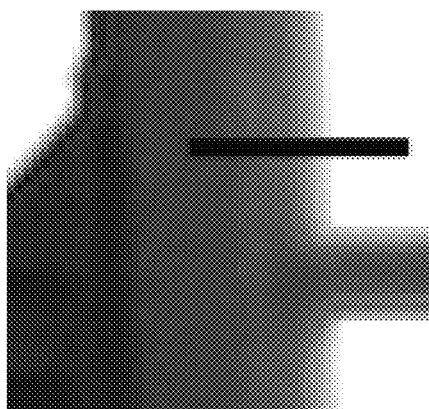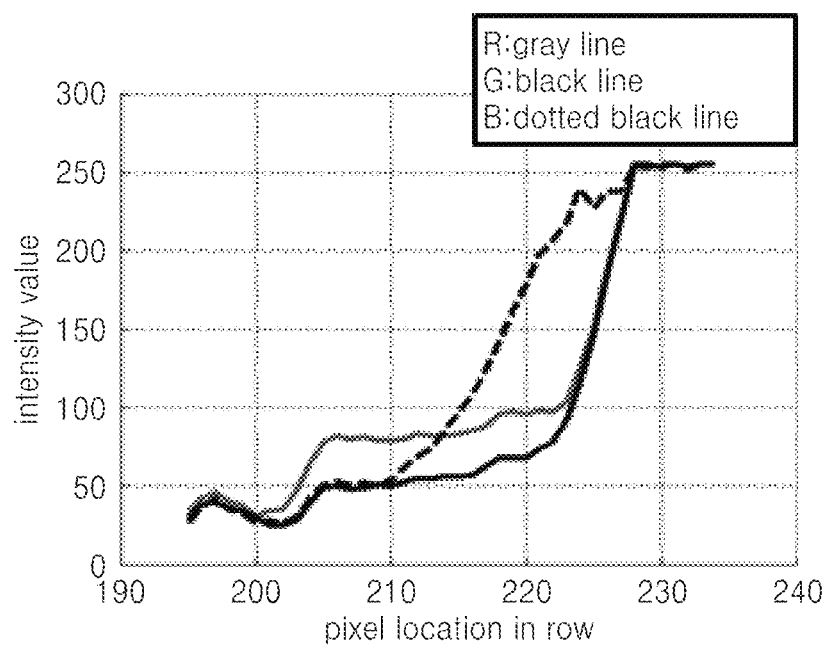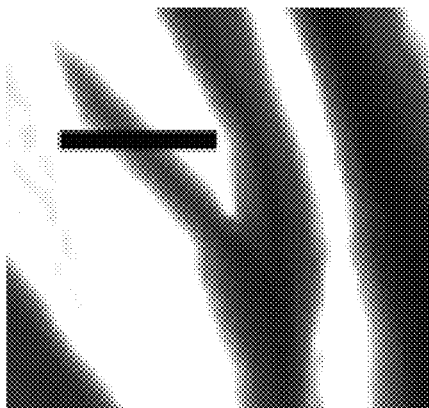
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FIG. 1A

FIG. 1B

FIG. 1C

FIG. 1D

FIG. 2

IMG

Detection Block

Gradient Magnitude Unit

21

$H((x,y)|(p,q))$

Gradient Direction Label Unit

23

$Lc(x,y)$

Near-saturation Region Detection Unit
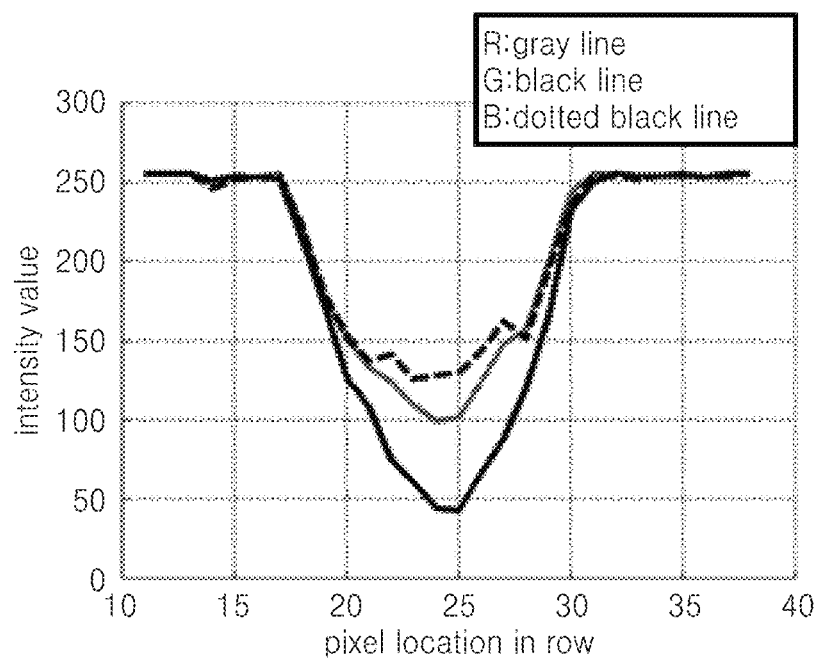
25

NSR'

20

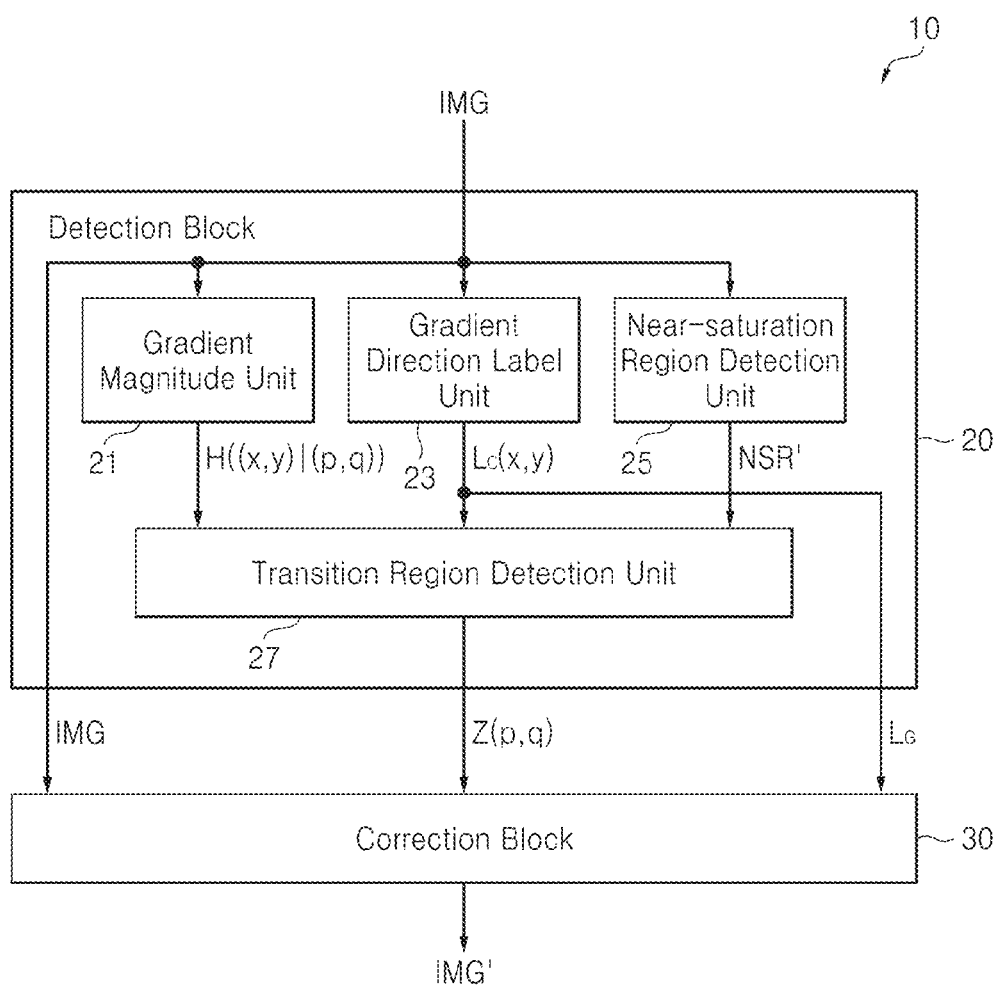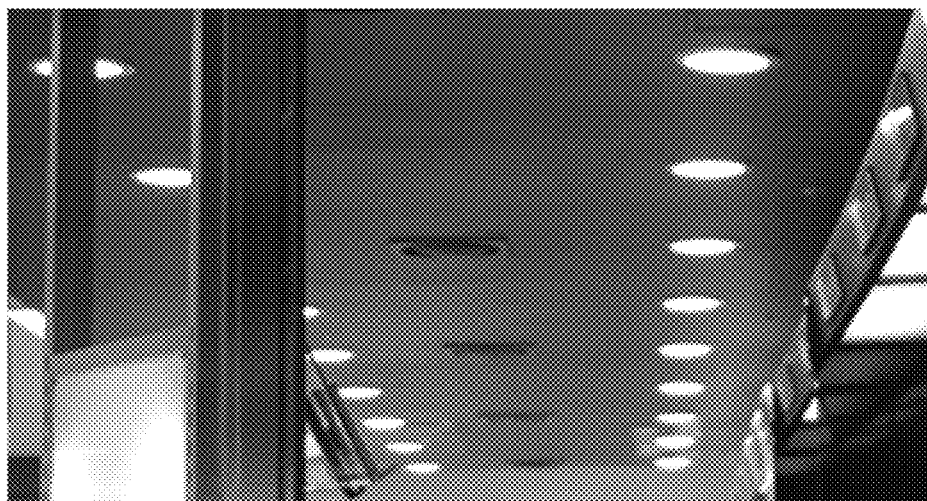Transition Region Detection Unit

27

IMG

$Z(p,q)$

Lc

Correction Block

30

IMG'

10

FIG. 3A

FIG. 3B

FIG. 4A

FIG. 4B

FIG. 5A

TR

FIG. 5B

TR
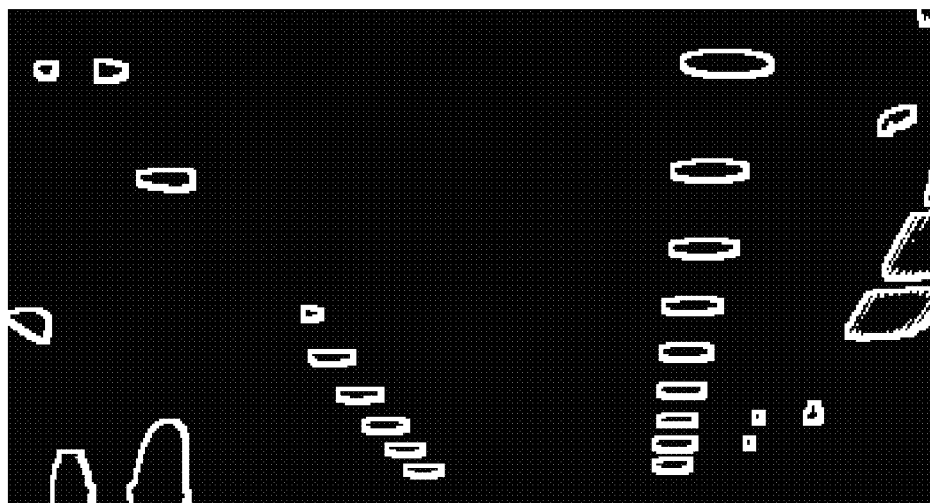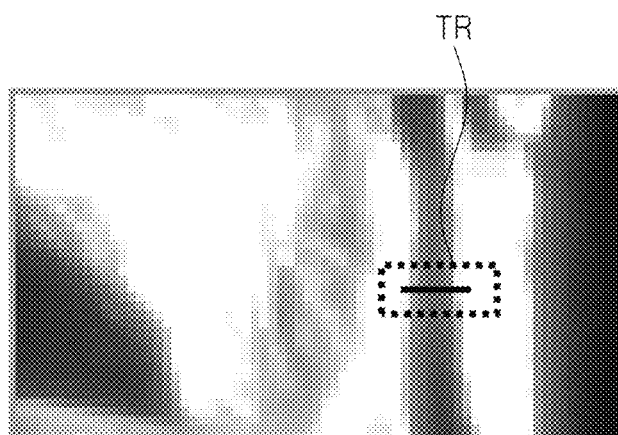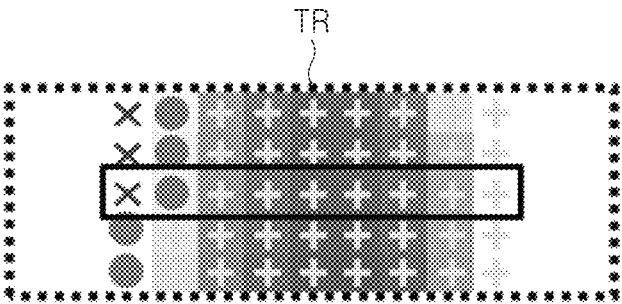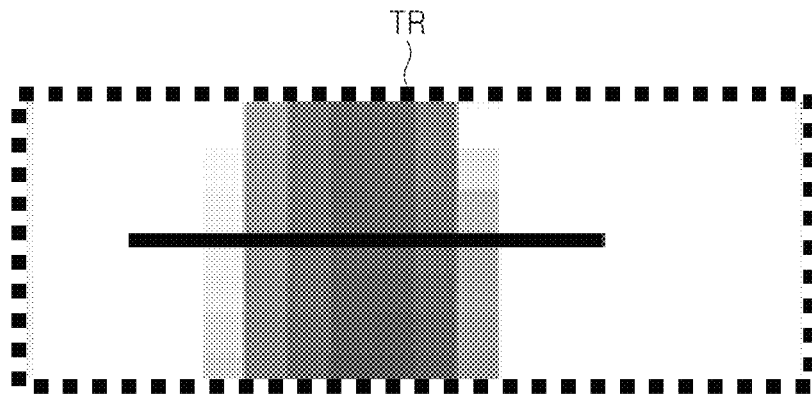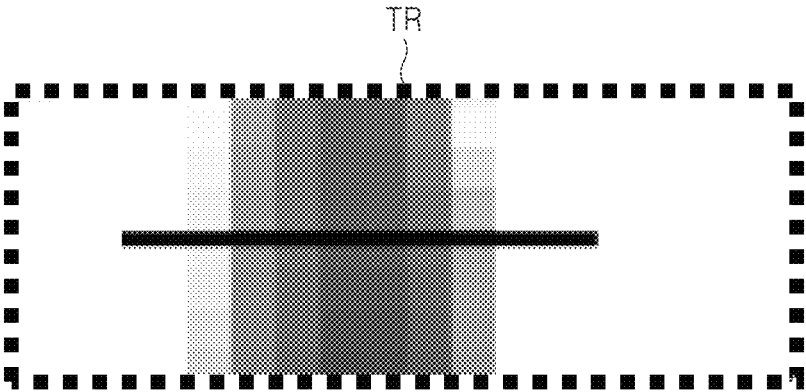
FIG. 5C
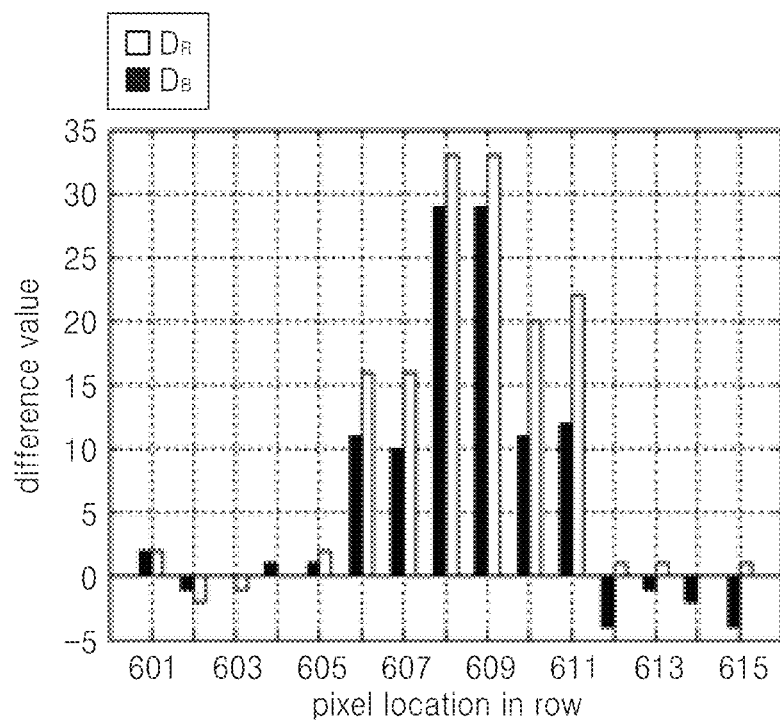
FIG. 5D

FIG. 5E

FIG. 5F

FIG. 6

FIG. 7

START

SELECT A MAXIMUM GRADIENT MAGNITUDE
AMONG GRADIENT MAGNITUDES FOR EACH
OF COLOR COMPONENTS IN AN IMAGE — S10

CALCULATE A BOUNDARY OF A DILATED
NEAR-SATURATION REGION IN THE IMAGE — S20

DETECT A TRANSITION REGION IN THE IMAGE
ACCORDING TO THE MAXIMUM GRADIENT
MAGNITUDE AND THE BOUNDARY OF THE
DILATED NEAR- SATURATION REGION — S30

REMOVE A COLOR FRINGE FROM THE
TRANSITION REGION — S40

END

FIG. 8

800

801

820 MEMORY

830 I/F

810 Processor

10 Image Signal Processor

FIG. 9

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METHOD AND DEVICE FOR PROCESSING AN IMAGE TO REMOVE COLOR FRINGE

CROSS-REFERENCE TO RELATED APPLICATIONS

A claim of priority under 35 U.S.C. §119 is made to Korean Patent Application No. 10-2013-0002806 filed on Jan. 10, 2013, the disclosure of which is hereby incorporated by reference in its entirety.

BACKGROUND

Embodiments of the inventive concept generally relate to image processing, and more particularly, to methods and devices for removing color fringe in a narrow color region of a digital image.

When a digital camera captures a color image of a live scene, a lens of the camera may not focus all colors to a convergence point. As a result, distortion may occur near boundaries of objects in the color image. This distortion is referred to herein as color fringe. Color fringe can become especially problematic as the resolution of the color image is increased or when the digital camera is relied on for detailed imagery.

Generally, color fringe results from chromatic aberration (color distortion) caused by an optical system and by a blooming effect. First, with respect to the optical system, chromatic aberration can result when RGB colors of light are not focused at a single point at the same time through a lens. That is, since the refractive indexes of the RGB colors differ from each other according to a wavelength, components of the three colors passing through a lens may not be focused on the same axis or plane.
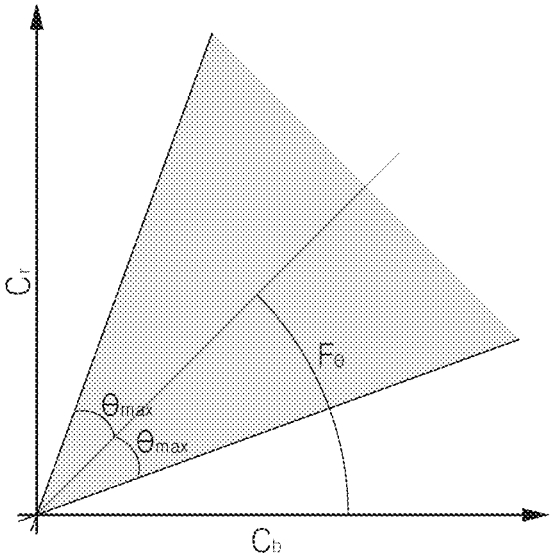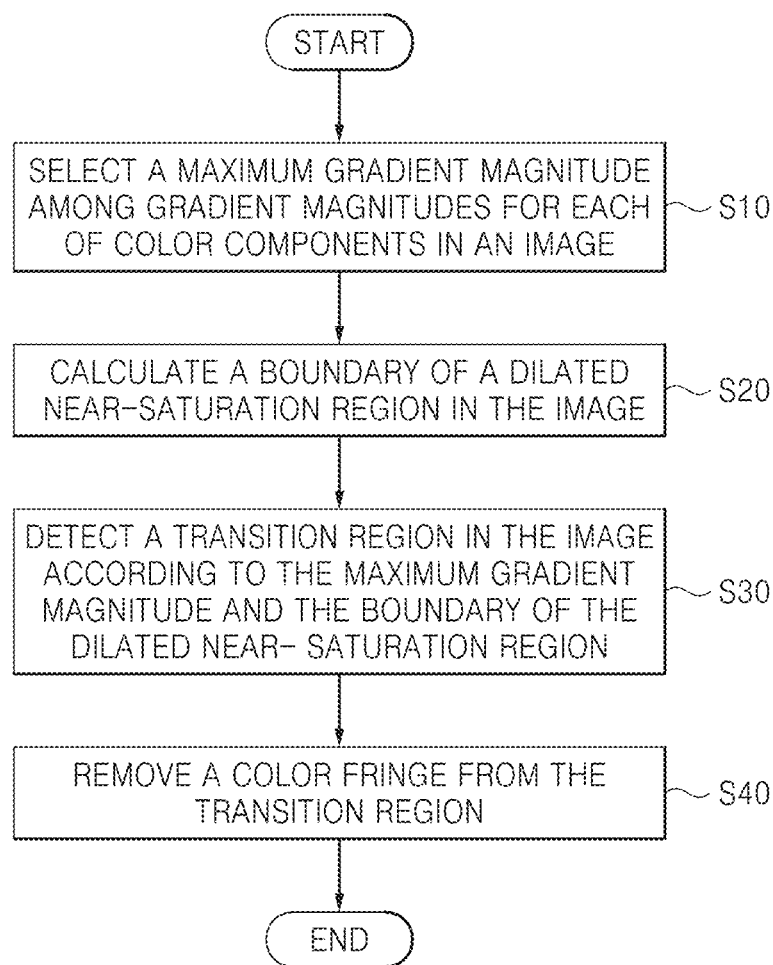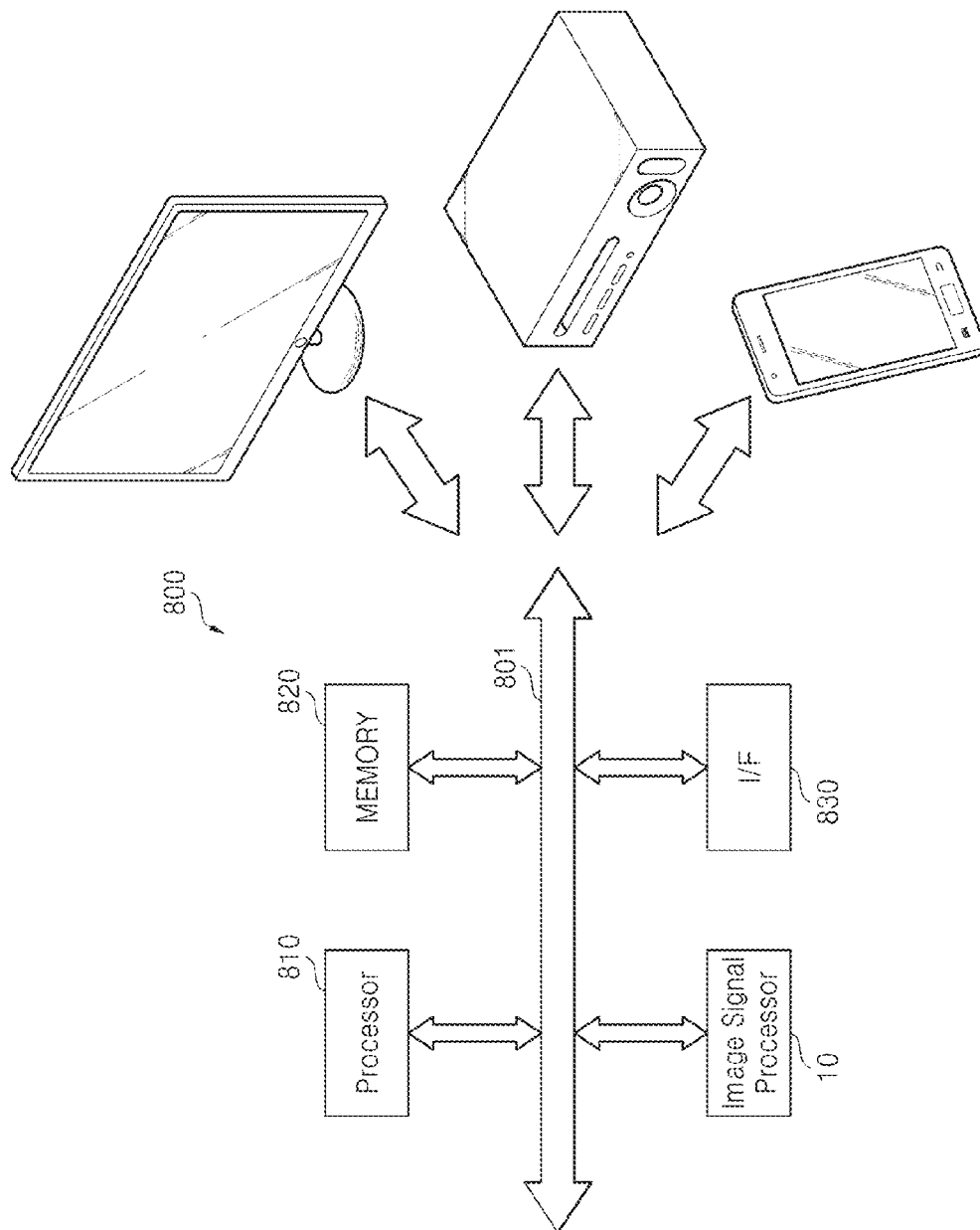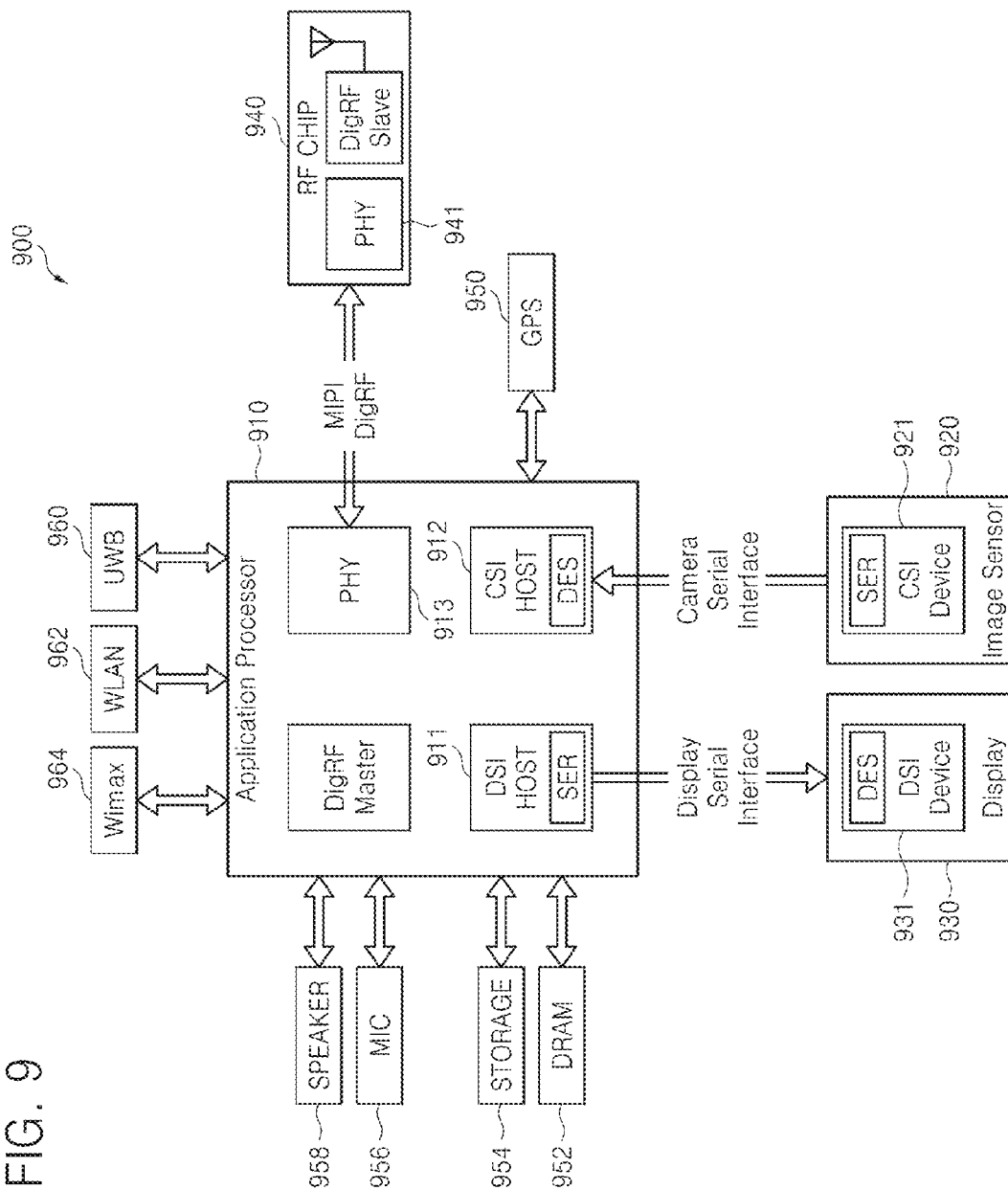
Second, with respect to the blooming effect, when a bright color is passed through an image sensor pixel for a continuous amount of time, accumulated charges may overflow into a potential wall. The overflowing charges may transfer to neighboring pixels, thereby causing color artifacts including a near-saturation region.

SUMMARY

An embodiment of the inventive concept is directed to a method for removing a color fringe, including selecting a maximum gradient magnitude among gradient magnitudes for each of color components in an image, calculating a boundary of a dilated near-saturation region in the image, detecting a transition region in the image according to the maximum gradient magnitude and a boundary of the dilated near-saturation region, and removing a color fringe from the transition region. Gradient magnitudes of each of the color components represent the greatest value among gradient magnitudes, which are calculated by using each of vertical, horizontal, diagonal, and anti-diagonal sobel masks, for each of the color components.

According to an example embodiment, a method for removing a color fringe may further include selecting a direction label for at least one of the color components at an arbitrary point of the image. The direction label is used for detecting the transition region.

The direction label is one of v, h, d and ad, and the v means vertical, the h means horizontal, the d means diagonal, and the ad means anti-diagonal. The dilated near-saturation region has a boundary value of 1 in the detected transition region. The maximum gradient magnitude is greater than a threshold value in the sensed transition region.

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When each of direction labels for each of the color components is selected, at least two of the direction labels for each of the color components are the same in the detected transition region.

The calculating a boundary of a dilated near-saturation region in the image includes calculating a near-saturation region by comparing a luma component with a threshold value in the image, calculating a dilated near-saturation region by using the near-saturation region and a dilation operation of a structuring element, and calculating a boundary of the expanded near-saturation region using a difference between the near-saturation region and the expanded near-saturation region.

The removing a color fringe from the transition region includes calculating leftmost pixel coordinates and rightmost pixel coordinates in the transition region according to the maximum gradient magnitude, and removing a color fringe from the transition region by using a maximum and a minimum value of color difference at the leftmost pixel coordinates and the rightmost pixel coordinates.

The removing a color fringe from the transition region according to an example embodiment includes calculating the degrees of color fringe occurrence for each color fringe in the transition region, determining a greatest value among the degrees of color fringe occurrence as a color degree, calculating a saturation value by using values of chroma components of the image, calculating weight values of each pixel in the transition region by using the color degree and the saturation value, and correcting the chroma components by using the weight values of each pixel.

Another example embodiment of the inventive concept is directed to an image processing method which includes receiving a digital image signal including color components for each of plural pixels constituting an image frame, selecting a maximum gradient magnitude among gradient magnitudes for each of the color components of the image frame, calculating a boundary of a dilated near-saturation region in the image frame, detecting a transition region in the image frame according to the maximum gradient magnitude and a boundary of the dilated near-saturation region, and generating a processed digital image signal in which a color fringe from the transition region has been removed.

Yet another example embodiment of the inventive concept is directed to an image processor, including a gradient magnitude unit selecting a maximum gradient magnitude among gradient magnitudes of each of color components in an image, a near-saturation region detection unit calculating a boundary of a dilated near-saturation region in an image, a transition region detection unit detecting a transition region in the image according to the maximum gradient magnitude and a boundary of the dilated near-saturation region, and a correction block removing a color fringe from the transition region.

An image processor according to an example embodiment may further include a gradient direction label unit selecting a direction label for at least one of the color components at an arbitrary point of the image.

The correction block calculates leftmost pixel coordinates and rightmost pixel coordinates in the transition region according to the maximum gradient magnitude, and removes a color fringe from the transition region by using a maximum and a minimum value of color difference at the leftmost pixel coordinates and the rightmost pixel coordinates.

The image processor may form part of a system which also includes a main processor, a memory and interface communicating over a bus system. The system may be embodied as at least one of a mobile phone, a smart phone, a tablet PC, a

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personal digital assistant (PDA), an enterprise digital assistant (EDA), a digital still camera, a digital video camera, a portable multimedia player (PMP), a personal navigation device or portable navigation device (PDN), a smart TV, handheld game console, a security camera, and an e-book.

According to an example embodiment, the correction block calculates the degrees of color fringe occurrence for each color fringe in the transition region, determines a greatest value among the degrees of color fringe occurrence as a color degree, calculates a saturation value by using values of chroma components in the image, calculates weight values of each pixel in the transition region by using the color degree and the saturation value, and corrects the chroma components by using the weight values of each pixel.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspect and features of the inventive concept will become readily apparent from the detailed description that follows, with reference to the accompanying drawing, in which:

FIG. 1A illustrates a portion of an image including a general fringed region;

FIG. 1B is a graph depicting an intensity value along a solid black line illustrated in FIG. 1A;

FIG. 1C illustrates a portion of an image including a narrow color region;

FIG. 1D is a graph depicting an intensity value along a solid black line illustrated in FIG. 1C;

FIG. 2 is a block diagram of an image processor according to an example embodiment of the inventive concept;

FIG. 3A illustrates a fringed image;

FIG. 3B illustrates a result of detecting a boundary of a near-saturation region of the image illustrated in FIG. 3A;

FIG. 4A illustrates a portion of a fringed image;

FIG. 4B is an enlarged image of a transition region of the image illustrated in FIG. 4A;

FIG. 5A illustrates a transition region of the image illustrated in FIG. 4B;

FIG. 5B illustrates a transition region where a fringe is removed using a fringe removal method according to an example embodiment of the inventive concept;

FIG. 5C is a graph depicting color difference values along a solid black line illustrated in FIG. 5A;

FIG. 5D is a graph depicting color difference values along a solid black line illustrated in FIG. 5A;

FIG. 5E is a graph depicting an intensity value along a solid black line illustrated in FIG. 5A;

FIG. 5F is a graph depicting an intensity value along a solid black line illustrated in FIG. 5B;

FIG. 6 is diagram representing a purple color fringe region in a C_bC_r plane;

FIG. 7 is a flowchart for explaining a color fringe removal method according to an example embodiment of the inventive concept;

FIG. 8 is a block diagram of an example embodiment of a system including the image processor illustrated in FIG. 2; and

FIG. 9 is a block diagram of another example embodiment of a system including the image processor illustrated in FIG. 2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1A illustrates a portion of an image including a general fringed region, and FIG. 1B is a graph depicting relative

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RGB intensity values at row pixel locations along the solid black line illustrated in FIG. 1A.

Referring to FIGS. 1A and 1B, intensity values in a general fringed region change abruptly from one constant value to another value, and an intensity value difference between these constant values is substantial. In a conventional art, such an intensity value difference may be may relied on to detect and remove color fringe within a digital image.

FIG. 1C illustrates an image including a narrow color region, and FIG. 1D is a graph depicting relative RGB intensity values along the solid black line illustrated in FIG. 1C.

Referring to FIGS. 1C and 1D, an intensity value is constant at two pixel regions on opposite sides of pixel region having relatively non-constant intensity values. A narrow color region refers to a case where an intensity value difference between the constant intensity values of the two pixel regions is zero or nearly zero. The previously mentioned conventional art relies on relies on a substantial intensity value difference pixel regions, and thus is not capable of removing color fringe in a narrow color region.

FIG. 2 is a block diagram of an image processor according to an example embodiment of the inventive concept. Referring to FIG. 2, an image signal processor 10 detects a transition region in an image IMG after receiving the image IMG, and removes (corrects) a color fringe in a detected transition region. A transition region is a pixel region where pixel intensity values rapidly change, and is also a candidate region of a color fringe. Also, the image IMG may include a narrow color region.

The image signal processor 10 includes a detection block 20 and a correction block 30. Each block 20 and 30 may be embodied in software, hardware, or a combination of software and hardware. According to this example embodiment, each block 20 and 30 is embodied in hardware.

The detection block 20 includes a gradient magnitude unit 21, a gradient direction label unit 23, a near-saturation region detection unit 25, and a transition region detection unit 27.

An image IMG includes color components. The color components of the example of this embodiment are RGB components. The RGB components are included in a RGB color space. According to an example embodiment, RGB components in an image IMG may be converted into YC_bC_r components. The YC_bC_r components are included in a YC_bC_r color space. The conversion is performed by the image signal processor 10. This may be represented as shown in equation 1.

$$\begin{bmatrix} Y \\ C_b \\ C_r \end{bmatrix} = \begin{bmatrix} 65.481 & 128.553 & 24.966 \\ -37.797 & -74.203 & 112.0 \\ 112.0 & -98.786 & -18.214 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} \quad \text{Equation 1}$$

The Y is a luma component, and C_b and C_r are blue difference and red difference chroma components, respectively.

A gradient magnitude unit 21 determines an initial point (p, q) in a transition region by comparing a gradient magnitude of a G component with an edge threshold value. When a gradient magnitude of a component G is greater than an edge threshold value, an initial point (p, q) in a transition region is determined.

According to an example embodiment, the gradient magnitude unit 21 may determine an initial point (p, q) in a transition region by comparing a gradient magnitude of a Y component with an edge threshold value.

The gradient magnitude unit 21 calculates a maximum magnitude (or value) among gradient magnitudes (or values) of four directions, i.e., vertical, horizontal, diagonal and anti-

diagonal, at an initial point (p, q). The gradient magnitude unit **21** calculates a maximum magnitude for each of RGB components. This may be represented as shown in equation 2.

$$E_C(x,y) = \max\{|E_{Cv}(x,y)|, |E_{Ch}(x,y)|, |E_{Cd}(x,y)|, |E_{Cad}(x,y)|\} \qquad \text{Equation 2}$$

$|E_{Cv}(x,y)|$, $|E_{Ch}(x,y)|$, $|E_{Cd}(x,y)|$, and $|E_{Cad}(x,y)|$ are gradient magnitudes calculated by using vertical v, horizontal h, diagonal d, and anti-diagonal ad sobel masks, respectively. C represents a component R, a component G or a component B. $E_c(x, y)$ has a maximum magnitude among $|E_{Cv}(x,y)|$, $|E_{Ch}(x,y)|$, $|E_{Cd}(x,y)|$, and $|E_{Cad}(x,y)|$.

According to an example embodiment, when RGB components are converted into YC_bC_r components, the gradient magnitude unit **21** may calculate a maximum magnitude among gradient magnitudes of four directions, i.e., vertical, horizontal, diagonal and anti-diagonal, by using equation 3 at an initial point (p, q).

$$E_Y^o(x,y) = \max\{|E_Y^v(x,y)|, |E_Y^h(x,y)|, |E_Y^d(x,y)|, |E_Y^{ad}(x,y)|\} \qquad \text{Equation 3}$$

$|E_Y^v(x,y)|$, $|E_Y^h(x,y)|$, $|E_Y^d(x,y)|$, and $|E_Y^{ad}(x,y)|$ are gradient magnitudes calculated by using vertical v, horizontal h, diagonal d and anti-diagonal ad sobel masks, respectively. Y represents a luma component. A chroma component C_b or C_r may be used instead of the luma component. $E_Y^o(x,y)$ has a maximum magnitude among $|E_Y^v(x,y)|$, $|E_Y^h(x,y)|$, $|E_Y^d(x,y)|$, and $|E_Y^{ad}(x,y)|$.

A gradient direction label unit **23** selects a direction label at an arbitrary point (x, y). This may be represented as shown in equation 4.

$$L_C(x,y) = \text{argmax } |E_{Ck}(x,y)| \qquad \text{Equation 4}$$

Here, $_k$ represents one of the v, h, d and ad. That is, $L_C(x,y)$ is a direction label, and the $L_C(x,y)$ has one of the v, h, d and ad. v represents vertical, h represents horizontal, d represents diagonal, and ad represents anti-diagonal. C represents a R component, a G component, or a B component.

According to an example embodiment, when RGB components are converted into YC_bC_r components in an image IMG, the gradient direction label unit **23** may select a direction label at an arbitrary point (x,y) by using equation 5.

$$L(p,q) = \text{argmax } |E_Y^o(p,q)| \qquad \text{Equation 5}$$

Here, o represents one of the v, h, d and ad. That is, L(p,q) is a direction label and has one of the v, h, d and ad. v represents vertical, h represents horizontal, d represents a diagonal, and ad represents an anti-diagonal. Y represents a luma component. A chroma component C_b or C_r may be used instead of the luma component.

The gradient direction label unit **23** uses a direction label L_G (p, q) of a G component at an initial point (p, q) to determine in which direction a color fringe has occurred. The G component is used as a reference signal among RGB components.

The gradient magnitude unit **21** calculates a maximum gradient magnitude by using equation 6.

$$H((x,y)|(p,q)) = \max\{|E_R(x,y)|, |E_G(x,y)|, |E_B(x,y)|\} \qquad \text{Equation 6}$$

A pixel(x, y) is adjacent to an initial point(p, q), and is located according to a direction embodied by a direction label $L_G(p, q)$. $L_G(p, q)$ represents a direction label at an initial point(p, q).

The gradient magnitude H((x,y)|(p,q)) has one of $|E_R(x,y)|$, $|E_G(x,y)|$ and $|E_B(x,y)|$. Each of $|E_R(x,y)|$, $|E_G(x,y)|$ and $|E_B(x,y)|$ is a value, calculated by using the equation 2, for each of RGB components.

When $L_G(p,q)=v$, y=q. When $L_G(p,q)=h$, x=p. x and y represent coordinates of a pixel. When $L_G(p,q)=d$, x=p−s and y=q+s. When $L_G(p,q)=ad$, x=p−s and y=q−s. s is a positive number and is related to a left conversion region of an initial point (p,q).

Likewise, when $L_G(p,q)=d$, x=p+t and y=q−s. When $L_G(p,q)=ad$, x=p+t and y=q+t. t is a positive number and is related to a right conversion region of the initial point (p,q).

According to an example embodiment, the gradient magnitude unit **21** may calculate a maximum gradient magnitude by using equation 7.

$$H((x,y)|(p,q)) = \max\ |E_{Cb}^{L(p,q)}(x,y)|, \{|E_{Cr}^{L(p,q)}(x,y)|\} \qquad \text{Equation 7}$$

A pixel(x, y) is adjacent to an initial point (p, q) and is located according to a direction embodied by a direction label L(p, q).

A maximum gradient magnitude H((x,y)|(p,q)) has one of $|E_{Cb}^{L(p,q)}(x,y)|$ and $|E_{Cr}^{L(p,q)}(x,y)|$. $|E_{Cb}^{L(p,q)}(x,y)|$ and $|E_{Cr}^{L(p,q)}(x,y)|$ are values, calculated by using the equation 3, for each of chroma components C_b or C_r.

When the following equations 8 and 9 are satisfied, respectively, a transition region detection unit **27** determines maximum values of s and t.

$$H((x,y)|(p,q)) \geq T_2 \qquad \text{Equation 8}$$

T_2 represents a threshold value. The transition region detection unit **27** determines if a maximum gradient magnitude H((x,y)|(p,q)) is greater than a threshold value T_2

$$(L_R(x,y)=L_G(x,y)) \text{ or } (L_R(x,y)=L_B(x,y)) \text{ or } (L_G(x,y)=L_B(x,y)) \qquad \text{Equation 9}$$

The transition region detection unit **27** compares direction labels of RGB components with each other. That is, the transition region detection unit **27** determines if at least two of direction labels of the RGB components are identical.

Edges occur in several directions in an image IMG, so that a conversion region should be determined according to a gradient direction to detect and correct a color fringe.

The near-saturation region detection unit **25** converts RGB components into a luma component Y in an image IMG.

$$Y = 65.481R + 128.553G + 24.966B + 16 \qquad \text{Equation 10}$$

The R, G, and B represent RGB components, and have a range from 0 to 1, respectively. The near-saturation region detection unit **25** calculates a boundary NSR' of a dilated near-saturation region $NSR_{dilation}$ in an image IMG as shown in equation 11.

$$NSR = NSR_{Dilation} - NSR \qquad \text{Equation 11}$$

NSR represents a near-saturation region, $NSR_{dilation}$ represents a dilated near-saturation region, and NSR' represents a boundary of the dilated near-saturation region.

When a value of Y is greater than or equal to a value of '230', NSR has a value of '1'. When a value of Y is less than a value of '230', NSR has a value of '0'.

The dilated near-saturation region $NSR_{dilation}$ is calculated by using a near-saturation region NSR and a dilation operation of a structuring element.

FIG. **3A** illustrates a fringed image and FIG. **3B** illustrates a result of detecting a boundary of a near-saturation region of the image illustrated in FIG. **3A**.

A boundary NSR' of a near-saturation region is expressed as a white pixel in FIG. **3B**. A boundary NSR' of a near-saturation region in the white pixel has a value of '1'. A boundary NSR' of a near-saturation region is a candidate for a color fringe region. A near-saturation region NSR should be considered because of the previously described blooming effect.

FIG. **4A** illustrates a portion of a fringed image, and FIG. **4B** is an enlarged image of a transition region TR illustrated in FIG. **4A**.

Referring to FIGS. **2**, **4A** and **4B**, a transition region detection unit **27** detects a transition region TR by using a maximum gradient magnitude H((x,y)|(p,q)) calculated by the gradient magnitude unit **21**, a direction label $L_C(x,y)$ selected by the gradient direction label unit **23**, and a boundary NSR' of a dilated near-saturation region calculated by the near-saturation region detection unit **25**.

According to an example embodiment, the transition region detection unit **27** may detect a transition region TR in a YC_bC_r space by using equations 7 and 11.

The transition region TR is expressed as a set of pixels. A pixel Z(p,q) in the transition region TR is represented as shown in equation 12.

$$Z(p, q) = \begin{cases} \{(i, j) \mid p - S < i < p + T, j = q\}, & \text{if } L_G(p, q) = v \\ \{(i, j) \mid i = p, q - S < j < q + T\}, & \text{if } L_G(p, q) = h \\ \{(i, j) \mid p - S < i < p + T, q - T < j < q + S\}, & \text{if } L_G(p, q) = d \\ \{(i, j) \mid p - S < i < p + T, q - S < j < q + T\}, & \text{if } L_G(p, q) = ad \end{cases} \qquad \text{Equation 12}$$

When a value of L_G (p,q), NSR'=1, and a condition of the equations 4 and 5 are satisfied, a pixel Z(p,q) is determined S and the T represent a leftmost location and a rightmost location in the transition region TR, respectively. That is, S and the T represent a maximum value of the positive number s and the positive number t, respectively. i and j represent coordinates of an image illustrated in FIG. **4A**.

Since a part of an image illustrated in FIG. **4A** is L_G(p,q)=v, a pixel Z(p,q) in the transition region TR is {(i,j)|p–S<i<p+T, j=q}.

Leftmost pixel coordinates and rightmost pixel coordinates in the transition region TR are defined as l(p,q) and r(p,q), respectively. l(p,q) and r(p,q) according to a gradient direction label are represented as shown in table 1.

TABLE 1

L_G (P,q)	l (p,q)	r (p,q)
V	(p – S,q)	(p + T,q)
H	(p,q – S)	(p,q + T)
D	(p – S,q + S)	(p + T,q – T)
Ad	(p – S,q – S)	(p + T,q + T)

A solid black line illustrated in FIG. **4A** corresponds to a black box illustrated in FIG. **4B**. 'o', 'x', and '+' illustrated in FIG. **4B** represent 'p', a left pixel of 'p', and a right pixel of 'p', respectively.

FIG. **5A** illustrates a transition region TR illustrated in FIG. **4B**, and FIG. **5B** illustrates a transition region where a fringe is removed by using a method for removing a fringe according to an example embodiment of the inventive concept. FIG. **5C** is a graph depicting color difference values along a solid black line illustrated in FIG. **5A**, and FIG. **5D** is a graph depicting color difference values along a solid black line illustrated in FIG. **5B**. FIG. **5E** is a graph depicting an intensity value along a solid black line illustrated in FIG. **5A**, and FIG. **5F** is a graph depicting an intensity value along a solid black line illustrated in FIG. **5B**.

Referring to FIGS. **5A** and **5C**, leftmost pixel coordinates l(p,q) are for a 604th pixel, and rightmost pixel coordinates r(p,q) are for a 612th pixel. A white bar represents a color difference value D_g between a R color element and a G color element, and a black bar represents a color difference value D_B between a B color element and a G color element.

When a color fringe occurs in the transition region TR, color difference values in the transition region TR are not within a range of color difference values at leftmost pixel coordinates l(p,q) and rightmost pixel coordinates r(p,q). At the leftmost pixel coordinates l(p,q), a color difference value D_R is 0 and a color difference value D_B is 1. At rightmost pixel coordinates r(p,q), a color difference value D_R is 1 and a color difference value D_B is –4. That is, color difference values in a transition region TR are not between –4 and 1.

Accordingly, the correction block **30** may correct or remove a color fringe in the transition region TR by using a maximum value (0 when a color difference value is Dr, 1 when a color difference value is D_B) and a minimum value (0 when a color difference value is D_R, –4 when a color difference value is D_B) of color difference at pixel coordinates l(p,q) and r(p,q). In addition, the correction block **30** may correct or remove a color fringe by using an intensity value of a G component in each pixel of the transition region TR. This may be represented with equations 13 through 15.

$$\hat{R}(x, y) = \begin{cases} \min\{D_R(l(p, q)), D_R(r(p, q))\} + G(x, y), & \text{if } D_R(x, y) < \min\{D_R(l(p, q)), D_R(r(p, q))\} \\ \max\{D_R(l(p, q)), D_R(r(p, q))\} + G(x, y), & \text{if } D_R(x, y) > \max\{D_R(l(p, q)), D_R(r(p, q))\} \\ R(x, y), & \text{otherwise} \end{cases} \qquad \text{Equation 13}$$

$$\hat{B}(x, y) = \begin{cases} \min\{D_B(l(p, q)), D_B(r(p, q))\} + G(x, y), & \text{if } D_B(x, y) < \min\{D_B(l(p, q)), D_B(r(p, q))\} \\ \max\{D_B(l(p, q)), D_B(r(p, q))\} + G(x, y), & \text{if } D_B(x, y) > \max\{D_B(l(p, q)), D_B(r(p, q))\} \\ B(x, y), & \text{otherwise} \end{cases} \qquad \text{Equation 14}$$

$$\hat{G}(x, y) = \hat{G}(x, y) \qquad \text{Equation 15}$$

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Each of $\hat{R}(x, y)$, $\hat{G}(x, y)$ and $\hat{B}(x, y)$ represents each of R, G and B color outputs in a corrected image. $D_R(l(p,q))$ represents a color difference value between a R color element and a G color element at leftmost pixel coordinates, $D_R(r(p,q))$ represents a color difference value between a R color element and a G color element at rightmost pixel coordinates, $D_B(l(p,q))$ represents a color difference value between a B color element and a G color element at leftmost pixel coordinates, and $D_B(r(p,q))$ represents a color difference value between a B color element and a G color element at rightmost pixel coordinates. (x,y) represents an element of a pixel Z(p,q) in the transition region TR.

The correction block **30** corrects a color fringe according to a direction embodied by a direction label LG(p,q) of a G component.

Referring to FIGS. **5A** and **5E**, intensity values of R, G and B in the transition region TR have different gradients.

Referring to FIGS. **5B** and **5D**, after a color fringe is removed from the transition region TR, color difference values in the transition region TR are located between color difference values at leftmost pixel coordinates l(p,q) and rightmost pixel coordinates r(p,q). A solid black line represents the leftmost pixel coordinates l(p,q) and a dotted black line represents the rightmost pixel coordinates r(p,q) in FIG. **5D**.

Referring to FIGS. **5B** and **5F**, intensity values of R, G, and B in a transition region TR have the same gradient.

FIG. **6** is a purple color fringe region on a C_bC_r plane. Referring to FIGS. **2** and **6**, the correction block **30** may remove a color fringe by using values of chroma components C_b and C_r and a direction label L(p,q) according to equation 5. The correction block **30** may calculate the degree of color fringe occurrence by using equation 16 in a detected transition region.

$$PD(x, y) = \frac{\theta_{max} - \min(|F_\theta - \theta(x, y)|, \theta_{max})}{\theta_{max}} \quad \text{Equation 16}$$

The PD(x,y) represents the degree of a purple color fringe, $\theta(x,y)$ represents a hue value, F_θ and θ_{max} represent a hue center and a hue angle, respectively. $\theta(x,y)$ has a range between $-180°$ and $180°$. A color fringe region in FIG. **6** is defined as a region having a range between $F_\theta-\theta_{max}$ and $F_\theta+\theta_{max}$. The degree of the color fringe occurrence PD(x,y) has a range between 0 and 1. When a hue value $\theta(x,y)$ is located outside the color fringe region, a pixel corresponding to the hue value is determined as a non-color fringe pixel.

As the degree of color occurrence PD(x,y) increases, a color fringe region increases.

The correction block **30** calculates the degrees of color fringe occurrence for each of red, green, blue and purple color fringes by using the equation 16. The degrees of color fringe for each color fringe RD(x,y), GD(x,y), BD(x,y), and PD(x,y) may be calculated by using parameter values of table 2.

TABLE 2

Type of Color Fringe	F_θ	θ_{max}
Purple	59.56°	41.09°
Red	99.78°	12.18°
Green	−115.07°	49.97°
Blue	−34.43°	28.50°

The correction block **30** determines a color degree CD(x,y) by using equation 17. That is, the correction block **30** deter-

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mines a greatest value among the degrees of color fringe occurrence for each of red, green, blue and purple color fringes as a color degree CD(x,y).

$$CD(x,y)=\max\{RD(x,y),GD(x,y),BD(x,y),PD(x,y)\} \quad \text{Equation 17}$$

RD(x,y), GD(x,y), BD(x,y), and PD(x,y) represent the degree of color fringe occurrence for each of red, green, blue and purple color fringes, respectively.

The correction block **30** calculates a saturation value SAT by using equation 18 to correct values of chroma components C_b and C_r.

$$SAT(i,j)=\sqrt{(C_b(i,j)-128)^2+(C_r(i,j)-128)^2} \quad \text{Equation 18}$$

Each of $C_b(i,j)$ and $C_r(i,j)$ is a value of chroma components Cb and Cr at a pixel (i,j) in a transition region. When the saturation value has a high value, a pixel value corresponding to the saturation value is included in a near saturation region NSR. As a color degree CD and a saturation value gets smaller, values of chroma components C_b and C_r get greater in correction of color fringe.

The correction block **30** calculates a hue value $\theta(x,y)$ to determine weight values for correcting values of chroma components C_b and C_r in a color fringe region. An example of calculation of the hue value $\theta(x,y)$ is explained in detail in U.S. Pat. No. 7,529,405.

The correction block **30** corrects chrominance values by using equation 19.

$$C'(x, y) = \frac{\sum_{m=-M}^{M} (W_{i,j}C(i, j))}{\sum_{m=-M}^{M} W_{i,j}} \quad \text{Equation 19}$$

C'(x,y) is corrected chrominance values, and C'(x,y) represents a value of a chroma component C_b or C_r in an image IMG. M represents the number of neighboring pixels according to a direction label. $W_{i,j}$ represents weight values of each pixel, and weight values $W_{i,j}$ of each pixel may be calculated by using a color degree CD and a saturation value SAT. This is expressed in equation 20.

$$W_{i,j}=(127-SAT(i,j)+1)(1-CD(i,j)+1) \quad \text{Equation 20}$$

FIG. **7** is a flowchart for explaining a method for removing a color fringe according to an example embodiment of the present inventive concept. Referring to FIGS. **2**, **5A** through **5F**, and **7**, the gradient magnitude unit **21** selects a maximum gradient magnitude H((x,y)|(p,q)) among gradient magnitudes $|E_R(x,y)|$, the $|E_G(x,y)|$ and the $|E_B(x,y)|$ of each of color components in an image IMG (S10).

The near-saturation region detection unit **25** calculates a boundary NSR'(x,y) of a dilated near-saturation region $NSR_{Dilation}$ in an image IMG (S20). The transition region detection unit **27** detects a transition region TR in an image IMG according to the maximum gradient magnitude and a boundary of the dilated near-saturation region (S30). The correction block **30** removes a color fringe from a transition region TR (S40).

FIG. **8** is a block diagram of an example embodiment of a system including the image processor illustrated in FIG. **2**. Referring to FIGS. **2** and **8**, a system **800** includes the image signal processor **10**, a processor **810**, a memory **820** and an interface (I/F) **830**, all communicating over a bus system **801**.

The processor **810** performs instructions for controlling the components **10**, **820** and **830**. The memory **820** may store instructions performed by the processor **810** and/or an image

IMG processed by the image signal processor **10**. The interface **830** may be embodied in an interface for outputting an image processed by the image signal processor **10**. According to an example embodiment, the interface **830** may be embodied in a wireless interface.

As schematically represented in FIG. **8**, system **800** may be embodied, as examples, in a mobile phone, a smart phone, a tablet PC, a personal digital assistant (PDA), an enterprise digital assistant (EDA), a digital still camera, a digital video camera, a portable multimedia player (PMP), a personal navigation device or portable navigation device (PDN), a smart TV, handheld game console, a security camera, or an e-book.

FIG. **9** is a block diagram of another example embodiment of the system including the image processor illustrated in FIG. **2**. Referring to FIG. **9**, a system **900** may be embodied in an image processing device which may use or support a mobile industry processor interface (MIPI®), e.g., a portable device such as a personal digital assistant (PDA), a portable media player (PMP), a mobile phone, a smart phone, or a tablet PC.

The system **900** includes an application processor **910**, an image sensor **920** and a display **930**. The application processor **910** may include the image signal processor **10** illustrated in FIG. **2**. A camera serial interface (CSI) host **912** embodied in the application processor **910** may perform a serial communication with a CSI device **921** of the image sensor **920**. According to an example embodiment, a de-serializer (DES) may be embodied in the CSI host **912**, and a serializer SER may be embodied in the CSI device **921**.

A display serial interface (DSI) host **911** embodied in the application processor **910** may perform a serial communication with a DSI device **931** of the display **930** through a display serial interface. According to an example embodiment, a serializer SER may be embodied in the DSI host **911**, and a de-serializer DES may be embodied in the DSI device **931**. The system **900** may further include a RF chip **940** which may communicate with the application processor **910**. A PHY **913** of the system **900** may transmit or receive data to/from a PHY **941** of the RF chip **940** according to MIPI DigRF.

The system **900** may include a GPS receiver **950**, a memory **952** such as a dynamic random access memory (DRAM), a data storage device **954** embodied in a non-volatile memory like a NAND flash memory, a microphone **956** or a speaker **958**. In addition, the system **900** may communicate with an external device by using at least one communication protocol or communication standard, e.g., ultra-wideband (UWB) **960**, Wireless LAN(WLAN) **962**, worldwide interoperability for microwave access (WiMAX) **964**, or long term evolution (LTE™:not shown).

As described above, a method and a device for removing a color fringe according to example embodiments of the inventive concept may process an image to detect and remove a color fringe of the image.

Although a few embodiments of the present general inventive concept have been shown and described, it will be appreciated by those skilled in the art that changes may be made in these embodiments without departing from the principles and spirit of the general inventive concept, the scope of which is defined in the appended claims and their equivalents.

What is claimed is:

1. An image processing method, comprising:

an image processor selecting a maximum gradient magnitude among gradient magnitudes for each of a plurality of color components of an image;

the image processor calculating a boundary of a dilated near-saturation region in the image;

the image processor detecting a transition region in the image according to the maximum gradient magnitude and the boundary of the dilated near-saturation region; and

the image processor removing a color fringe from the transition region to obtain a processed image.

2. The method of claim **1**, wherein each of the gradient magnitudes for each of the color components represents a greatest value among gradient magnitudes, calculated by using each of vertical, horizontal, diagonal and anti-diagonal sobel masks, for each of the color components.

3. The method of claim **1**, further comprising selecting a direction label for at least one of the color components at an arbitrary point of the image, wherein the direction label is used to detect the transition region.

4. The method of claim **3**, wherein the direction label is one of v, h, d and ad, and wherein v represents vertical, h represents horizontal, d represents diagonal, and ad represents anti-diagonal.

5. The method of claim **1**, wherein a boundary value of the dilated near-saturation region in the detected transition region is 1.

6. The method of claim **1**, wherein the maximum gradient magnitude is greater than a threshold value in the detected transition region.

7. The method of claim **3**, wherein, when each of direction labels is selected for each of the color components, at least two of the direction labels for each of the color components are the same in the detected transition region.

8. The method of claim **1**, wherein calculating a boundary of a dilated near-saturation region in the image includes:

calculating a near-saturation region by comparing a luma component value with a threshold value in the image;

calculating a dilated near-saturation region by using the near-saturation region and a dilation operation of a structuring element; and

calculating a boundary of the dilated near-saturation region using difference between the near-saturation region and the dilated near-saturation region.

9. The method of claim **1**, wherein removing a color fringe in the transition region includes:

calculating leftmost pixel coordinates and rightmost pixel coordinates in the transition region according to the maximum gradient magnitude; and

removing a color fringe from the transition region by using a maximum value and a minimum value of a color difference at the leftmost pixel coordinates and the rightmost pixel coordinates.

10. The method of claim **1**, wherein removing a color fringe from the transition region includes:

calculating a degree of color fringe occurrence for each color fringe in the transition region;

determining a greatest value among the degrees of the color fringe occurrence as a color degree;

calculating a saturation value by using values of chroma components in the image;

calculating weight values of each pixel in the transition region by using the color degree and the saturation value; and

correcting the chroma components by using the weight values of each pixel.

11. An image processing method, comprising:

an image processor receiving a digital image signal including a plurality of color components for each of plural pixels constituting an image frame;

the image processor selecting a maximum gradient magnitude among gradient magnitudes for each of the color components of the image frame;

the image processor calculating a boundary of a dilated near-saturation region in the image frame;

the image processor detecting a transition region in the image frame according to the maximum gradient magnitude and the boundary of the dilated near-saturation region;

the image processor generating a processed digital image signal in which a color fringe from the transition region has been removed.

12. The method of claim **11**, wherein each of the gradient magnitudes for each of the color components represents a greatest value among gradient magnitudes, calculated by using each of vertical, horizontal, diagonal and anti-diagonal sobel masks, for each of the color components.

13. The method of claim **11**, further comprising selecting a direction label for at least one of the color components at an arbitrary point of the image, wherein the direction label is used to detect the transition region.

14. The method of claim **13**, wherein the direction label is one of v, h, d and ad, and wherein v represents vertical, h represents horizontal, d represents diagonal, and ad represents anti-diagonal.

15. An image processor, comprising:

a gradient magnitude unit for selecting a maximum gradient magnitude among gradient magnitudes for each of a plurality of color components in an image;

a near-saturation region detection unit for calculating a boundary of a dilated near-saturation region in the image;

a transition region detection unit for detecting a transition region in the image according to the maximum gradient magnitude and the boundary of the dilated near-saturation region; and

a correction block for removing a color fringe from the transition region.

16. The image processor of claim **15**, further comprising a gradient direction label unit for selecting a direction label for at least one of the color components at an arbitrary point in the image.

17. The image processor of claim **15**, wherein the correction block calculates leftmost pixel coordinates and rightmost pixel coordinates of the transition region according to the maximum gradient magnitude, and removes the color fringe from the transition region by using a maximum value and a minimum value of a color difference at the leftmost pixel coordinates and the rightmost pixel coordinates.

18. The image processor of claim **15**, wherein the correction block calculates a degree of color fringe occurrence for each color fringe in the transition region, determines a greatest value among the degrees of color fringe occurrence as a color degree, calculates a saturation value by using values of chroma components in the image, calculates weight values of each pixel in the transition region by using the color degree and the saturation value, and corrects the chroma components by using the weight values of each pixel.

19. A system comprising the image processor of claim **15**, a host processor, a memory and interface communicating over a bus system.

20. The system of claim **19**, wherein the system is embodied as at least one of a mobile phone, a smart phone, a tablet PC, a personal digital assistant (PDA), an enterprise digital assistant (EDA), a digital still camera, a digital video camera, a portable multimedia player (PMP), a personal navigation device or portable navigation device (PDN), a smart TV, handheld game console, a security camera, and an e-book.

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